NRPB

Documents of the NRPB

Guidance on Restrictions on Food and Water Following a Radiological Accident

VOLUME 5 NO 1 1994

National Radiological Protection Board
Chilton, Didcot, Oxon OX11 0RQ

The National Radiological Protection Board was created by the Radiological Protection Act 1970. The functions of the Board are to give advice, to conduct research, and to provide technical services in the field of protection against both ionising and non-ionising radiations.

In 1977 the Board received Directions under the Radiological Protection Act which require it to give advice on the acceptability to and the application in the UK, of standards recommended by international or intergovernmental bodies, and to specify emergency reference levels (ERLs) of dose for limiting radiation doses in accident situations.

Documents of the NRPB contain both the formal advice of the Board on standards of protection as well as guidance on their application in practice.

DOCUMENTS OF THE NRPB

Guidance on Restrictions on Food and Water Following a Radiological Accident

VOLUME 5 NO 1 1994

National Radiological Protection Board
Chilton, Didcot, Oxon OX11 0RQ

GUIDANCE ON RESTRICTIONS ON FOOD AND WATER FOLLOWING A RADIOLOGICAL ACCIDENT

ABSTRACT

This document sets out the Board's advice on intervention levels for food following a radiological accident. It replaces previous Board advice on this subject. The advice is given in the context of recent recommendations from the International Commission on Radiological Protection and of Regulations from the Council of the European Communities on intervention levels for food. The Board advises that the Council Regulations will restrict radiation doses from food to low levels. Reduction of the Council intervention levels to more restrictive levels is therefore unlikely ever to be justified on the grounds of reducing radiation risk. However, the Board advises that, following a very severe accident, it could be justified to relax the Council intervention levels by up to a factor of ten. For individual foods or radionuclides, where it could be demonstrated that individual doses would be restricted to levels of a few millisievert, a greater degree of relaxation could be justified.

The Regulations do not specify levels for drinking water supplies. The Board has therefore recommended UK Action Levels for water. In circumstances where replacement of supplies is extremely difficult, relaxation of the Action Levels by factors of two or three may be justified.

The Board advises that both the Council intervention levels and the Action Levels represent a balance between the harms and benefits likely to arise from intervention; they do not represent a boundary between safe and unsafe levels. Consumption of food or water at concentrations in excess of these levels for short periods need not be a cause for concern.

PREPARED BY M MORREY AND C A ROBINSON

INTRODUCTION

1 The Board has a responsibility to specify emergency reference levels (ERLs) of dose for members of the public. The Board is also responsible for providing guidance to government departments and other appropriate bodies on the derivation of ERLs relating to radiation exposure and radioactive materials in the public environment. A statement of principles for the protection of the public and workers in the event of an accidental release of radioactive materials into the environment was published in 1990[1] and numerical criteria for emergency reference levels for the emergency countermeasures of sheltering, evacuation and stable iodine administration were also given[2]. This document gives advice on the control of food and water. It replaces the earlier guidance on food and water intervention given in NRPB-DL10[3]. It is intended for application to all types of radiological accident that result in the contamination of food or water supplies in the UK.

2 Since it is cautiously assumed that even very low levels of exposure to radiation (whether natural or man-made) will increase an individual's risk of developing cancer or other damage, it is not possible to specify threshold levels of radionuclide contamination in food below which the food is 'safe'. Therefore the Board's principles[1] state that intervention should be both justified (ie do more good than harm) and optimised (maximise the net benefit). In other words, a balance needs to be struck between the harm likely to result from consuming contaminated food and the harm caused by preventing its consumption (including the potential curtailment of other social programmes in order to finance compensation and replacement foods, and the restrictions on lifestyle imposed on farmers). In the extreme, of course, it must be more beneficial to consume food with even fairly high levels of contamination than for an individual to starve to death: however, this is very unlikely ever to be the choice facing authorities in the UK, following a nuclear accident. It is therefore important for the Board to provide authoritative advice on the radiological implications of preventing the consumption of food and water contaminated above specified concentrations. These radionuclide concentration levels may be called either intervention levels (ILs) or action levels, to indicate that above these levels specified actions should be carried out. It is important to recognise that ILs do not define the boundary between safe and unsafe levels, but represent a balance between competing harms and benefits. Therefore the optimum value of an IL is at least partly dependent on circumstances. For example, following a very severe accident, in which a substantial fraction of UK produce was contaminated, optimum ILs would be likely to be higher than those following a very small accident, owing to the level of costs and disruption involved.

3 In providing advice, the Board must take account of recent Regulations from the Council of the European Communities[4-6] which specify ILs for radioactive contamination in marketed foods and animal feeds (here termed CFILs – Council Food Intervention Levels). These CFILs will be legally binding on the UK following a future accident, although provision has also been made for member states to agree revisions to the CFILs shortly after an accident. Therefore, for those foods covered by the Regulations, it is appropriate for the Board only to comment on the radiological implications of the CFILs and potential revisions to these, rather than to recommend independent ILs. Discussion of the radiological implications of the CFILs forms the major part of this document.

4 The Council Regulations do not give CFILs for all forms of drinking water supply. It is therefore appropriate for the Board to specify UK Action Levels for drinking water. These are developed in this document.

CFILs

5 The Council Regulations[4-6] on ILs for radioactive contamination in marketed foods would be legally binding on the UK in the event of a future nuclear accident*. For application of these Regulations in the UK, food marketed is likely to be defined as food *supplied* (ie it is unnecessary for money to change hands, and the food need not be in the form in which it will be consumed). The CFILs represent a Communities judgement on the optimum balance between the beneficial and harmful consequences of introducing food restrictions in the European Communities. In case these CFILs should prove inappropriate under the specific circumstances of a future accident, provision has been made within the Regulations for the CFILs to be revised shortly after an accident. Such a revision depends on a qualified majority agreement by the member states.

6 The CFILs are listed in Table 1. Twenty are for foods[4,5], and three are for animal feeds[6]. The CFILs for foods are divided into four groups of radionuclides (radiostrontium, radioiodine, alpha-emitting radionuclides, and other radionuclides with relatively long half-lives) and five food categories (baby foods, dairy foods, other major foods, minor foods and liquid foods – these food groups are defined in Appendix A). The CFILs for animal feeds apply to radioisotopes of caesium only, and are specified for food intended for three categories of animal (pigs; poultry, lambs and calves; other). By using this grouping, the CFILs are kept to a manageable number, while, at the same time, important differences in the behaviour of radionuclides and people's dietary habits are taken into account.

7 Within each radionuclide and food group it is the sum of the concentrations of all the specified radionuclides in that food which is to be compared with the CFIL. For example, if both ^{134}Cs and ^{137}Cs are present within a consignment of meat, then the concentrations of the individual radionuclides should be added together before comparison with the CFIL of 1250 Bq kg^{-1}.

8 The CFILs are intended to be applied independently of one another; if the level for one radionuclide group in a given food category is exceeded, then that food will be banned, regardless of the concentration of other radionuclides in that food, or of the concentration of that radionuclide in other foods. Similarly, if the summed contributions of radionuclides within each of two groups were each more than 50% (but less than 100%) of the CFILs given for each group, then the food will not be banned.

ICRP recommendations

9 A number of other international bodies have issued guidance on food intervention. However, only the Council Regulations would be binding on the UK. To put the CFILs into context, they are compared below with the latest guidance from the International Commission on Radiological Protection (ICRP). A discussion of the other major international guidance on food intervention is given in Appendix B.

*These Regulations do not apply to food contaminated by the accident at the Chernobyl nuclear plant.

TABLE 1
CFILs for foods and animal feeds[a,b]

Radionuclide	Intervention levels (Bq kg^{-1}) Baby foods	Dairy produce	Minor foods	Other foods	Liquid foods	ICRP advice[c]
Isotopes of strontium, notably ^{90}Sr	75	125	7 500	750	125	100–1 000[d]
Isotopes of iodine, notably ^{131}I	150	500	20 000	2 000	500	1 000–10 000
Alpha-emitting isotopes of plutonium and transplutonium elements	1	20	800	80	20	10–100
All other radionuclides of half-life greater than 10 days, notably ^{134}Cs and ^{137}Cs[e]	400	1 000	12 500	1 250	1 000	1 000–10 000
Animal feed intended for	**Intervention levels[f] (Bq kg^{-1})**					
Pigs	1 250					
Poultry, lambs and calves	2 500					
Other	5 000					

Notes
(a) From references 4, 5 and 6.
(b) The food categories are defined in Appendix A.
(c) From reference 7.
(d) By inference from reference 7.
(e) This category includes ^{103}Ru and ^{106}Ru. ^{14}C, ^{3}H and ^{40}K are not included in this group.
(f) Intervention levels are for ^{134}Cs and ^{137}Cs only.

10 ICRP has recently produced revised guidance for intervention following nuclear accidents[7]. This replaces that previously given in Publication 40[8]. In summary, ICRP now recommends that intervention should be taken by restricting a single food if individual dose reductions in excess of 10 mSv in a year can be achieved, provided that there are nutritionally adequate alternative food supplies. It is difficult to make a generic comparison of advice provided in terms of dose averted and the CFILs, since the dose averted by application of the CFILs depends on the maximum individual doses that would have been received from food in the absence of food bans. These, of course, would vary, depending on the scale of the accident and subsequent environmental conditions. However, if the maximum doses received following application of the CFILs are significantly less than the ICRP recommendation of 10 mSv in a year, then it is unlikely that application of the ICRP advice would require more restrictive banning following any particular accident. ICRP further indicates that the dose criterion implies that ILs adopted for food should be in the range 1000–10 000 Bq kg^{-1} for radionuclides such as ^{137}Cs and ^{131}I, and in the range 10–100 Bq kg^{-1} for radionuclides such as ^{239}Pu. The implication can be drawn that the appropriate IL for radiostrontium should lie between these two ranges (since the dose per unit intake factors for strontium radioisotopes are between those for radiocaesium and those for plutonium isotopes).

11 The CFILs are compared with the new ICRP recommendations[7] in Table 1. It can be seen that, with the exception of 'minor foods' (of which only small quantities are likely to be eaten) and 'baby foods' (for which the CFILs are deliberately very restrictive), the CFILs generally lie within the ICRP recommended ranges. The exceptions are two of the CFILs for radioiodine (those for dairy produce and liquid foods) which are slightly more restrictive than the ICRP recommendations.

Dose implications of adopting the CFILs

12 Following a radiological accident affecting the UK, there will be a distribution of radionuclide concentrations in food, as discussed in Appendix C. The distribution for each radionuclide will range from zero to a maximum level determined by the characteristics of the accident and meteorological and environmental conditions. If this maximum level is higher than the relevant CFIL, then the consequence of implementing the CFILs will be to truncate the distribution of radionuclide concentrations in the food supply at the level of the CFIL. The dose an individual receives from ingestion reflects the levels of radionuclide concentrations in the food consumed. Therefore, even in the absence of intervention, individual doses would vary; the effect of implementing the CFILs would be to restrict the highest doses.

13 In this document, discussion of the radiological implications of implementing the CFILs will concentrate on the restriction they impose on individual doses*. Although implementation of the CFILs would have some effect on the collective dose received by the UK population, this effect would not be as important as the effect on the individual doses of those most exposed. This is because, except following an accident in which a large proportion of the UK food supply was highly contaminated, the doses received by most of the population would be small (or zero), even in the absence of countermeasures. Clearly there are also social and political factors involved[10] in the specification of the CFILs, but the assessment of these is beyond the Board's remit.

Maximum individual doses implied by the CFILs

14 The relationship between food ILs and the resulting individual doses is complex, and difficult to calculate generically. These doses depend on the sources and composition of an individual's diet and the variation of radionuclide concentrations within the food as a function of time. This is discussed more fully in Appendix C. What is clear, however, is that a dose estimate based on assuming all diet is continously contaminated at the level of the CFILs will grossly overestimate the true doses.

15 Those individuals whose doses would be significantly restricted by implementation of the CFILs fall into two groups. These will be discussed in turn.

Consumers of locally contaminated food

16 Most individuals obtain a proportion of their food from local sources and the remainder (the majority) from more distant sources. The people most affected by implementation of the CFILs are therefore individuals living in an area where food is contaminated above the level of the CFILs, and who consume a relatively large quantity of locally produced food. Information on the likely dietary habits of such people is available from previous studies[11]. If the accident has heavily contaminated local produce, then, unless the accident is very severe, it is likely that most food obtained

*The doses calculated in this document are effective doses, calculated according to the new recommendations in ICRP Publication 60[9]. Some radionuclides irradiate single organs preferentially, but since the levels of dose calculated are low, consideration of single organ doses does not affect the conclusions.

from elsewhere will not be significantly contaminated. Taking account of both this and the likely reduction of radionuclide concentration in food with time, indicative upper levels of individual dose can be estimated for this group using the following assumptions:

(a) the individual consumes a particular food type in above-average ('critical group') quantities[12],

(b) 10% of the individual's consumption of a particular food is continuously contaminated at the level of the CFIL for 1 year by the principal radionuclide in each radionuclide group (with the exception of food contaminated with radioiodine, which is assumed contaminated at the CFIL for 2 months only, owing to its short radioactive half-life),

(c) the remainder of the diet is uncontaminated.

The Board judges that these assumptions will not underestimate the maximum individual doses actually received by this group. Doses have been calculated for a range of foods (domestic fruit, potatoes, milk, meat, fish, cereals and green vegetables) and for four age groups (infants, children and adults – all on mixed diets – and babies on an all-milk diet).

17 The individual doses calculated for adults, infants and babies are given in Table 2 for each food and radionuclide. (The doses for children are broadly similar to the doses given in the table.) It should be remembered that, in general, these represent the upper levels of individual dose which might be received from food after an accident; except in very extreme circumstances, most individuals would receive very much lower doses than these. Since these doses reflect critical group intake rates, it is inappropriate to sum the doses over all the foods listed to obtain a likely total dose from ingestion. Moreover, it is unlikely that more than one or two food types or radionuclide categories would significantly contribute to the dose received. Summation of the doses in Table 2 over food types or radionuclide categories would therefore result in a substantial overestimation of the total dose.

18 In general, the doses for each food range between a few hundredths of a millisievert and about half a millisievert in a year. These doses are significantly lower than the ICRP recommendation of 10 mSv in a year and are similar to those received naturally every year (see Table 3). These doses do not pose a major risk to health and, according to ICRP guidance, need not be reduced further.

Individuals consuming their own food

19 Some individuals consume large amounts of certain foods from a limited geographical area, eg farmers consuming milk from their own farms and individuals growing nearly all their own vegetables. In areas where these foods are contaminated at levels close to, or in excess of, the CFILs, some of these individuals may be exposed to higher doses than those indicated in Table 2. Moreover, since most of the individuals in this group will be consuming their own produce, implementation of the CFILs (which act only on food *supplied*, ie food which 'changes hands') will not directly restrict their intakes of radionuclides. It is clearly important that individuals in this group are fully informed of the likely levels of contamination in their food, the health risks associated with consuming this food, and the action which they could take to reduce these risks. In providing this information, it is important to recognise that consumption of some local

TABLE 2
Indicative maximum individual doses implied by consumption of foodstuffs for 1 year at the CFILs[a,b]

Age group	Food group[c]	Intake of contaminated food[d] (kg y^{-1})	Committed effective dose for critical groups[e] (mSv)			
			^{90}Sr	^{131}I[f]	^{239}Pu	^{137}Cs
Adults	Domestic fruit	8	0.2	0.06	0.2	0.1
	Potatoes	8	0.2	0.06	0.2	0.1
	Green vegetables	4.5	0.1	0.03	0.1	0.07
	Cattle meat	4.5	0.1	0.03	0.1	0.07
	Milk	25	0.09	0.05	0.1	0.3
	Fish	3.5	0.07	0.03	0.08	0.06
	Cereals	10	0.2	0.07	0.2	0.2
Infants[g]	Domestic fruit	6	0.5	0.4	0.3	0.08
	Potatoes	4	0.4	0.2	0.2	0.05
	Green vegetables	1.5	0.1	0.09	0.08	0.02
	Cattle meat	1	0.09	0.06	0.05	0.01
	Milk	30	0.5	0.5	0.4	0.3
	Fish	0.85	0.08	0.05	0.04	0.01
	Cereals	2.5	0.2	0.2	0.1	0.03
Babies[h]	Milk	30	0.6	0.2	0.2	0.3

Notes

(a) The CFILs are defined in Table 1.

(b) Following imposition of food restrictions using the CFILs the UK population would receive a wide distribution of doses from food. Most of the doses would be very small. Those given here indicate the upper levels of individual dose that might be received. It is inappropriate to sum the doses for each food in order to obtain a meaningful estimate of the total dose an individual might receive (see text).

(c) The food categories used in this table are based on those for which intake rates are given in reference 12.

(d) Total intake rates are taken from reference 12. The assumption is made that 10% of an individual's diet is contaminated continuously at the CFIL.

(e) Dose per unit intake values are taken from reference 13.

(f) Owing to its short half-life, ^{131}I doses are calculated assuming 10% of an individual's diet is contaminated continuously at the CFIL for 2 months.

(g) Infants are assumed to be 1 year old and on a mixed diet. The CFILs for infants are assumed to be the same as those used for adults.

(h) For babies, assumed to be 3 months old, the CFILs for baby foods are used. It is cautiously assumed that the diet consists entirely of formula milk. The intake rate corresponding to the 95th percentile given in reference 12 was assumed. The dose per unit intake values used (Sv Bq^{-1}) were as follows[14]: ^{90}Sr 2.6 10^{-7}; ^{131}I 2.4 10^{-7}; ^{137}Cs 2.1 10^{-8}; ^{239}Pu 6.5 10^{-6}.

produce contaminated to levels even exceeding the CFILs should not be a cause for concern; the doses in Table 2 were determined assuming that 10% of each food was contaminated continuously at the CFILs throughout the year.

Implications of revisions to the CFILs

20 The Council Regulations provide for the CFILs to be revised following an accident, if there is a qualified majority agreement by the member states. It is therefore useful for the Board to provide advice on the radiological implications of changing the CFILs, as one input to the UK contribution to discussions on potential revisions to the CFILs.

21 It has already been demonstrated that application of the CFILs would, in general, constrain nearly all individual doses below fairly low levels. Revising the CFILs to be

TABLE 3
Annual exposure of the UK population from natural sources of radiation[a]

Source	Average dose (mSv y^{-1})	Variation[b] (mSv y^{-1})
Cosmic	0.26	0.2–0.3
External irradiation from terrestrial sources	0.35	0.1–1.0
Exposure to radon and its decay products	1.2	0.3–100
Exposure to thoron and its decay products	0.1	0.05–0.5
Internal irradiation from terrestrial sources	0.3[c]	0.1–1.0
Total	2.2[d]	1–100

Notes
(a) Taken from reference 15.
(b) In some cases these are little better than order of magnitude estimates.
(c) ^{40}K in diet contributes about 0.18 mSv y^{-1} on average.
(d) In Cornwall, the average annual individual dose is about 10 mSv.

more restrictive would constrain the upper end of the distribution of individual doses still further. Revising them to be less restrictive would, of course, provide less constraint on the upper individual doses. From the doses estimated in Table 2, it is clear that, for some food and radionuclide categories, making the CFILs less restrictive by a factor of twenty might result in some individuals receiving doses of around 10 mSv in the first year following an accident. For most food and radionuclide categories, however, a dose estimate of 10 mSv implies relaxation of the CFILs by a much greater factor than this. ICRP recommends that if dose reductions of about 10 mSv can be achieved in a year for a particular food, then action should be taken to do this. The Board endorses this view. As stated earlier, it is difficult to draw a direct relationship between dose averted (the ICRP criterion) and dose received. Generally, if doses received in the first year were well below 10 mSv then it would be unlikely to be justified to reduce the doses still further. However, it would be difficult to justify inaction if the dose received might exceed 10 mSv. Therefore, the Board would not support a general relaxation of the CFILs by factors in excess of ten, except in circumstances where alternative food supplies could not be made available. However, it could be justified, on radiation risk grounds, to make individual CFILs less restrictive by greater factors where it could be demonstrated that the resulting individual doses would be restricted to levels of a few millisievert.

22 The Board has undertaken a study of the relative sensitivity of some of the consequences of food restrictions, to changes in intervention level. This study is described in Appendix D and the results are illustrated in Table 4. It can be seen that as the IL is varied, the monetary costs of the ban change more rapidly than does either the individual or collective dose averted. In other words, as the IL for a particular food and radionuclide is gradually made more restrictive, so it becomes increasingly expensive to avert a further increment of collective dose from this pathway. This is a consequence of the rapid increase in area over which food must be restricted, as ILs are reduced. This is a factor which, of course, should be carefully balanced against the low level of the doses likely to be received following implementation of the CFILs before a decision is taken to make the CFILs more restrictive.

TABLE 4
Implications of changes to the CFILs

Change in intervention level (relative to CFIL)	Approximate change in cost	Approximate change in collective dose averted
÷2	×3	×1.5
×2	÷2.5	÷1.5
×10	÷30	÷4

Note These are derived as discussed in Appendix D: the values are approximate and strictly only applicable to the site and accidents studied. However, the broad implications of this table are generally valid, ie that as the IL is varied, the monetary costs of the ban change more rapidly than does either the individual or collective dose averted.

Guidance on food intervention

23 It has been demonstrated that the upper levels of individual dose likely to result from application of the CFILs would be low. The Board therefore advises that, in terms of the radiation risk posed to individuals, ample protection would be afforded by adoption of the CFILs following an accident. The Board also emphasises that the CFILs represent a Communities view on the appropriate balance between the competing harms and benefits of implementing food restrictions; consumption of food contaminated at levels well in excess of the CFILs for short periods (up to a few weeks) need not give rise to significant radiation risks. Therefore, for the purpose of avoiding significant doses from food consumption, the immediate withdrawal of contaminated food supplies is, in general, not essential.

24 The Board recognises that the CFILs apply only to marketed foods (ie any food supplied). Although it is difficult to enforce restrictions on the consumption of foods that are not marketed, the Board recommends that the CFILs should be used to trigger advice intended to restrict the intake of radionuclides by individuals producing their own food.

25 In view of the relatively low doses likely to result after imposition of food bans at the CFILs, the Board advises that, following an accident, revision of the CFILs towards more restrictive ILs would be unlikely to be justified on radiation risk grounds. However, a general relaxation of the CFILs by up to about a factor of ten could be justified, particularly if a major proportion of UK agriculture was affected. It could also be justified, on radiation risk grounds, to make individual CFILs less restrictive by greater factors, where it could be demonstrated that the resulting individual doses would be restricted to levels of a few millisievert in a year.

RESTRICTIONS ON WATER SUPPLIES

26 The Council Regulations include the specification of CFILs for the radioactive contamination of liquid foods[4]. These are listed in Table 1. Liquid foods are defined to include fruit and vegetable juices, non-alcoholic beverages and alcoholic beverages (see Appendix A). 'Non-alcoholic beverages' include only bottled waters but the Regulation also states that these CFILs 'should be applied to drinking water supplies (eg 'tap' water) at the discretion of competent authorities in member states'. It is therefore appropriate for the Board to advise on ILs for drinking water, and to consider the CFILs for liquid foods as a starting point for its advice.

Maximum individual doses implied by the CFILs for liquid foods

27 Following an accident, water supplies may become contaminated in one of two main ways: either a release of radionuclides may occur directly to a water body sourcing a supply, or environmental processes may deposit or leach radionuclides into water bodies following a release to the atmosphere. In the former case, it is likely that only one water supply will become contaminated, while in the latter case the contamination is likely to be much more widespread (see Appendix E). Once contamination has entered the water supply, the doses received by individuals drinking the water will depend on the level of contamination and its variation with time, and the range of sources from which they obtain their drinking water. Therefore, as for food, in the absence of intervention a distribution of doses will occur. The effect of banning water supplies contaminated above a certain level will be to constrain the individual doses at the upper end of this distribution. These individuals will be those who obtain most of their drinking water from a single, relatively highly contaminated supply.

28 Indicative maximum individual doses resulting from the intake of water contaminated at the CFILs for liquid foods can be estimated using the assumption that all of an individual's 'tap' water consumption (ie intake of water from a local water supply, whether directly or in beverages, as opposed to intake of water in food or bottled drinks) is contaminated at the level of the CFILs throughout the year (with the exception of ^{131}I for which a period of 2 months is assumed, owing to its short radioactive half-life). This assumption is different from that made for doses from food consumption (see paragraphs 14–18), since it is usual for many individuals to obtain most of their drinking water from a single supply (eg the local mains supply). A survey carried out in 1980 indicated that, in Great Britain, approximately half of an individual's total water intake comes from tap water; the remainder is consumed in the form of milk, fruit juice or bottled drinks[16]. Therefore, doses have been calculated for adults, children and infants, each consuming tap water at the rates determined in the 1980 study, with the assumption that the water is continuously contaminated at the level of the CFILs for liquid foods. These dose estimates are presented in Table 5.

29 It can be seen that, with one exception, all the doses are below 3 mSv in a year. The exception is the implied dose to adults from radiocaesium isotopes, which is a little higher at around 5 mSv. Although these doses are somewhat higher than those calculated for foods, they are still fairly low (most of them are similar to, or less than, the average annual dose received from natural background radiation) and they generally compare favourably with ICRP advice. Therefore, it would not be reasonable to advise that more restrictive ILs should be adopted for mains supply drinking water than those specified by the Council Regulation for liquid foods. In fact, the Board advises that the consumption of water contaminated well in excess of these levels, for limited periods (eg a few weeks), need not constitute a significant risk to health.

UK Action Levels for drinking water supplies

Recommended Action Levels

30 The Board recommends that the CFILs for liquid foods should be adopted as Action Levels for all drinking water supplies in the UK. These Action Levels are listed in Table 6. They should be used to indicate whether action should be taken to provide alternative supplies following a radiological accident. (Other simple actions, such as boiling water, will not reduce radioactive contamination.) It is emphasised that if individuals were to

TABLE 5
Indicative maximum individual doses from drinking water consumption implied by CFILs for liquid foods for 1 year[a]

Age group and intake of 'tap' water[b]	Radionuclide	Committed effective dose[c,d] (mSv)
Adults	^{90}Sr	1.4
391 l y^{-1}	$^{131}I^{e}$	0.7
	^{239}Pu	2.2
	^{137}Cs	5.1
Children	^{90}Sr	1.1
197 l y^{-1}	$^{131}I^{e}$	1.0
	^{239}Pu	1.4
	^{137}Cs	2.0
Infants	^{90}Sr	2.6
172 l y^{-1}	$^{131}I^{e}$	2.6
	^{239}Pu	2.2
	^{137}Cs	1.7

Notes

(a) Following imposition of water restrictions using the CFILs for liquid foods the UK population would receive a wide distribution of doses from water consumption. Most of the doses would be very small. Those given here indicate the upper levels of individual dose that might be received.

(b) From reference 16.

(c) Assuming all water consumed from drinking water supplies is continuously contaminated at the levels of the CFILs for liquid foods (see Table 1).

(d) Dose per unit intake values taken from reference 13.

(e) Owing to its short half-life, ^{131}I doses are only calculated for 2 months.

TABLE 6
Recommended UK Action Levels for drinking water supplies[a]

Radionuclide	Action Levels[b] (Bq l^{-1})
Isotopes of strontium, notably ^{90}Sr	125
Isotopes of iodine, notably ^{131}I	500
Alpha-emitting isotopes of plutonium and transplutonium elements	20
All other radionuclides of half-life greater than 10 days, notably radioisotopes of caesium and ruthenium[c]	1000

Notes

(a) These Action Levels refer to all water supplies which are intended, at least in part, for drinking and food preparation purposes. See text for advice on the urgency with which contaminated drinking water supplies should be replaced.

(b) It is the sum of the concentrations of all the radionuclides included within a category and detected in the water which should be compared with the Action Level.

(c) This category does not include ^{14}C, ^{3}H or ^{40}K.

drink water contaminated well in excess of these Action Levels for limited periods (eg a few weeks), this need not pose a significant radiological hazard. Thus the immediate withdrawal of drinking water supplies is, in general, not essential. However, every effort should be made to provide alternative supplies quickly (at least within a few weeks), in order to maximise the dose reduction achieved.

31 The urgency of provision of alternative drinking water supplies should reflect the amount by which the Action Levels are exceeded; priority should be given to those supplies that exceed them by the greatest margin. The form of contamination should also be taken into account when assigning priorities. If the contamination is mainly of short-lived radionuclides, restrictions are only likely to be effective in reducing doses if applied quickly. In this case alternative supplies provided after a few weeks would be ineffective since the bulk of the dose would already have been received.

32 The Board advises that these Action Levels should be used to trigger the total substitution of any water supplies that are intended, at least in part, for drinking or food preparation purposes. Substitution of solely that part intended for drinking or food preparation purposes may be considered as an interim measure while full substitution is organised, or in extreme situations where full substitution of the supply cannot be achieved. In such situations it is advised that water exceeding the Action Levels may still be used safely for washing, toilet flushing and other (non-ingestion) purposes over protracted periods.

33 In monitoring drinking water supplies, it should be remembered that contaminated surface waters and unblended rainwater may have concentration levels that are significantly higher than those in drinking water supplies derived from them (see Appendix E). In particular, there is likely to be a reduction between the levels of contamination in surface waters and those in tap water. It is therefore important that drinking water is monitored for comparison with the Action Levels after any normal water treatment process, and that tap water should not be banned solely on the basis of surface water measurements. However, measurements in surface waters can be useful indicators of the scale and duration of any potential contamination.

Revisions to the Action Levels

34 Although the UK Action Levels for drinking water are linked to the CFILs for liquid foods, they should be recognised as separate from them. Provision has been made for a revision of the CFILs, if necessary, after an accident, but the Board does not recommend that the Action Levels should automatically be revised in response to a revision of the CFILs for liquid foods. If there are insurmountable difficulties associated with providing alternative water supplies (eg owing to very widespread contamination of supplies or the physical remoteness of particular individuals and communities), then the Board advises that, if possible, these should be dealt with on a case by case basis, rather than by introducing a more general relaxation of the Action Levels. In this way, the greatest dose reduction may be achieved. If it became necessary to use less restrictive ILs than the Action Levels for certain supplies, then the Board recommends that a general relaxation of the Action Levels by factors of two or three could be justified on radiation risk grounds.

ANIMAL FEEDS

35 The Council Regulations include CFILs for animal feeds (see Table 1). Inspection of Table 1 indicates that these levels are very similar to those adopted for human consumption. Setting the CFILs at these levels takes no account of farming practices and animal metabolism which could substantially reduce the levels of radionuclide contamination in animal food products. For example, an animal fed on uncontaminated

feed for a few weeks before slaughter will excrete most of the radiocaesium in its body tissues. The Board recognises that the UK is legally bound to implement the CFILs for animal feeds in the event of a future accident. However, it advises that if, following an accident, consideration is given to revision of these CFILs, then there is no reason, on radiation risk grounds, for any limits to be set for radionuclides in animal feeds.

SUMMARY

36 This document sets out the Board's advice on intervention levels for foods following a radiological accident. Regulations have been issued by the Council of the European Communities specifying intervention levels (here termed CFILs) for radioactive contamination in marketed foods and animal feeds. These Regulations become binding on the UK following a future accident. The levels specified for foods are consistent with the latest advice from ICRP. If restrictions were imposed on food at the levels of the CFILs, then the doses received by most individuals in the UK would be very small. Estimates of the upper levels of dose that would be received are, at most, similar to those from natural radiation exposure. The Regulations also provide for revisions to the CFILs to be made after an accident, if appropriate. The Board advises that, in terms of reducing radiation dose, revision of the CFILs to more restrictive levels would be unlikely to be warranted, but that, in situations where a major proportion of the UK food supply was contaminated, a general relaxation of the CFILs by up to a factor of ten could be justified. For individual food and radionuclide categories, where it could be demonstrated that individual doses would be restricted to levels of a few millisievert, a greater degree of relaxation could be justified.

37 The Council Regulations do not provide intervention levels for drinking water supplies. The Board recommends UK Action Levels for drinking water that are equal to the CFILs specified in the Council Regulation for liquid foods. Consumption of water contaminated at these levels would result in small doses. The Action Levels are applicable to any water supplies that are intended, at least in part, for drinking and food preparation purposes. They apply to the radionuclide concentrations in water as it is consumed; these concentrations are likely to be lower than those measured in surface waters. The Board emphasises that water may be consumed safely at levels well in excess of the Action Levels, at least for short periods, and may also be used safely, on a continuing basis, for non-ingestion purposes (eg washing and toilet flushing) at even higher contamination levels, if no other supplies are available. Thus the immediate withdrawal of drinking water supplies is not in general necessary. However, every effort should be made to provide alternative supplies quickly in order to maximise the dose reduction achieved. The Board recommends that revision of the CFILs for liquid foods should not automatically result in a corresponding general revision to the Action Levels for drinking water. Rather, if particular difficulties over the provision of alternative water supplies arise in specific areas, then, if possible, these should be dealt with on a case by case basis. In this case, relaxation of the Action Levels by factors of two or three could be justified on radiation risk grounds.

38 The Board stresses that the CFILs and Action Levels represent a balance between the harms and benefits of intervention; they do not represent safety limits. For this

reason, immediate substitution of food or water supplies is unlikely ever to be necessary on radiation risk grounds. However, intervention should be implemented as soon as reasonable following contamination of a particular food, in order to maximise the dose reduction achieved.

REFERENCES

1 NRPB. Statement by the National Radiological Protection Board: Principles for the protection of the public and workers in the event of accidental releases of radioactive materials into the environment and other radiological emergencies. *Doc. NRPB,* **1**, No. 4, 1–4 (1990).

2 NRPB. Emergency reference levels of dose for early countermeasures to protect the public. *Doc. NRPB,* **1**, No. 4, 5–33 (1990).

3 Linsley, G S, Crick, M J, Simmonds, J R, and Haywood, S M. Derived emergency reference levels for the introduction of countermeasures in the early to intermediate phases of emergencies involving the release of radioactive materials to atmosphere. Chilton, NRPB-DL10 (1986).

4 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

5 CEC. Council Regulation (Euratom) No. 944/89 laying down maximum permitted levels of radioactive contamination in minor foodstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L101/17 (1989).

6 CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of a radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).

7 ICRP. Principles for intervention for protection of the public in a radiological emergency. ICRP Publication 63. *Ann. ICRP,* **22**, No. 4 (1993).

8 ICRP. Protection of the public in the event of major radiation accidents: Principles for planning. ICRP Publication 40. *Ann. ICRP,* **14**, No. 2 (1984).

9 ICRP. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. *Ann. ICRP,* **21**, Nos 1–3 (1991).

10 Jammet, H, Dunster, H J, Luykx, F, and Gouvras, G. L'établissement dans la Communauté Européene de niveaux d'intervention dérivés pour la contamination des produits alimentaires – la suite d'un accident nucleaire. IN Proceedings conference on radiation protection in nuclear energy, Sydney, April 1988. Vienna, IAEA (1988).

11 Stather, J W, Dionian, J, Brown, J, Fell, T P, and Muirhead, C R. The risks of leukaemia and other cancers in Seascale from radiation exposure: Addendum to Report 171. Chilton, NRPB-R171 Addendum (1986) (London, HMSO).

12 Robinson, C A. Generalised habit data for radiological assessments. Chilton, NRPB (to be published).

13 Phipps, A W, Kendall, G M, Stather, J W, and Fell, T P. Committed equivalent organ doses and committed effective doses from intakes of radionuclides. Chilton, NRPB-R245 (1991) (London, HMSO).

14 Phipps, A, NRPB. Private communication (1993).

15 Hughes, J S, and O'Riordan, M C. Radiation exposure of the UK population – 1993 review. Chilton, NRPB-R263 (1993) (London, HMSO).

16 Hopkin, S M, and Ellis, J C. Drinking water consumption in Great Britain: A survey of drinking habits with special reference to tap-water-based beverages. Medmenham, Water Research Centre, Technical Report TR137 (1980).

Appendix A

SUMMARY OF THE DEFINITION OF THE COUNCIL FOOD CATEGORIES[1–3]

For all food groups, the level applicable to concentrated or dried products is calculated on the basis of the reconstituted product as ready for consumption.

Baby foods	Foodstuffs intended for the feeding of infants during the first 4–6 months of life, which meet, in themselves, the nutritional requirements of this category of person and are put up for retail sale in packages that are clearly identified and labelled 'food preparation for infants'
Dairy produce	Milk and cream only
Minor foods	Condiments, eg herbs and spices Uncommon root vegetables, eg arrowroot Fruit peel Plants and parts of plants used for perfumes, pharmaceuticals or insecticides Gums and vegetable extracts Fats and oils Caviar Parts of the cocoa seed Truffles Preserved fruit and nuts Yeasts Vitamins
Liquid foods	Fruit and vegetable juices Bottled water Beer and other fermented beverages Wines Spirits Vinegar
Other foods	All foods other than those listed above

REFERENCES

1 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

2 CEC. Council Regulation (Euratom) No. 944/89 laying down maximum permitted levels of radioactive contamination in minor foodstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L101/17 (1989).

3 CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of a radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).

Appendix B

INTERNATIONAL GUIDANCE ON FOOD INTERVENTION

Introduction

A number of international bodies have issued guidance on food intervention levels (ILs). The latest advice from ICRP and the Regulations issued by the Council of the European Communities relating to a future accident have been discussed in the main text. The nature and status within the UK of other major guidance is described here.

Council of the European Communities

Following the accident at Chernobyl, the Council has issued a number of Regulations concerning contamination levels in food that will apply for future accidents[1-4]. These Regulations are intended to ensure uniformity of standards across the European Communities and would become legally binding in the UK following an accident anywhere in the world. Three of the Regulations[1-3] lay down ILs (CFILs – Council Food Intervention Levels) for radioactive contamination in marketed foods, including liquid foods and animal feeds. They are discussed in the main text and so will not be discussed further here.

There are further Regulations dealing with foods imported from, and exported to, countries outside the European Communities[4,5]. The ILs for imports only apply to foods contaminated following the accident at the Chernobyl nuclear power plant[5]. It is understood that they would not apply following a future accident; instead the CFILs would apply. The Regulation for exports endorses the use of the CFILs[4].

World Health Organization

The World Health Organization (WHO) issued guidelines on ILs for radionuclides in food in 1988[6]. The purpose of this guidance was to assist national authorities in developing appropriate ILs for food. This guidance is intended to apply in the 'far-field', ie for countries at some distance from the site of the accident. A simple (and conservative) methodology is offered for determining ILs, based on a limiting annual individual dose and the assumption that all food is contaminated at the IL. In addition, indicative levels are provided for a range of foods and water, based on above-average world consumption rates and on a limiting dose of 5 mSv in a year. WHO stresses that these ILs are intended only as guidelines and that they should be modified for the conditions of a particular accident.

The WHO guidelines are not legally binding on the UK, and are different in detail from the CFILs, which would be legally binding in the event of an accident. However, in general, the ILs indicated by WHO are similar to, or less restrictive than, the CFILs. In the case of a few food categories the WHO ILs for the more radiotoxic isotopes (principally ^{239}Pu) are slightly more restrictive than the CFILs. In view of the conservative assumptions made in their derivation, these differences are not considered to be important.

Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC), a body set up jointly by the Food and Agriculture Organization (FAO) of the United Nations and WHO, issued guideline levels for radionuclides in food in 1989[7]. These guideline levels apply only to international trade involving potentially contaminated food. They are largely based on the WHO guidance described above, but have been greatly simplified. Guideline levels are expressed as radionuclide concentrations in food, and there is no distinction between food type, except for baby food. The level proposed for baby food for ^{131}I is significantly more restrictive than the WHO value, but otherwise the levels are broadly similar.

The CAC levels are broadly similar to the CFILs for the more restrictive food categories (particularly baby foods, dairy produce and liquid foods), but are significantly more restrictive if applied to foods that are not eaten in large volumes (eg herbs and spices). As with the WHO levels, the CAC guidelines are not legally binding in the UK.

International Atomic Energy Agency

The International Atomic Energy Agency (IAEA) is about to publish revised advice on ILs for food[8], within the context of a revision to the Basic Safety Standards of FAO, IAEA, ILO, NEA(OECD), PAHO and WHO. These Safety Standards are widely adopted around the world and form an important source of guidance on all aspects of radiological protection. The revised ILs will be expressed as radionuclide concentrations in different types of foods, and the values will be very similar to the CAC levels. Again, the IAEA ILs will not be legally binding in the UK.

REFERENCES

1 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

2 CEC. Council Regulation (Euratom) No. 944/89 laying down maximum permitted levels of radioactive contamination in minor foodstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L101/17 (1989).

3 CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of a radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).

4 CEC. Council Regulation (Euratom) No. 2219/89 on the special conditions for exporting foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L211 (1989).

5 CEC. Council Regulation (Euratom) No. 3955/87 on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power station. *Off. J. Eur. Commun.*, L371 (1987).

6 World Health Organization. Derived intervention levels for radionuclides in food, guidelines for application after widespread radioactive contamination resulting from a major reactor accident. Geneva, WHO (1988).

7 Codex Alimentarius Commission. Contaminants: Guideline levels for radionuclides in food following accidental nuclear contamination for use in international trade. Geneva, WHO, Supplement 1 to Codex Alimentarius, Volume XVII (1989).

8 IAEA. Intervention criteria in a nuclear or radiation emergency. Vienna, IAEA-SS109 (to be published).

Appendix C

MOVEMENT OF RADIONUCLIDES THROUGH THE FOODCHAIN

Introduction

In order to arrive at advice on food intervention, it is necessary to consider the manner in which food becomes contaminated and the relative importance of different food pathways and radionuclides, and how these relate to doses to people. In particular, there is no simple relationship between the size and composition of a release of radioactivity and the individual doses that result from ingestion of contaminated foods. This appendix discusses this relationship. Further information may be obtained elsewhere[1,2].

Incorporation in plants and animals

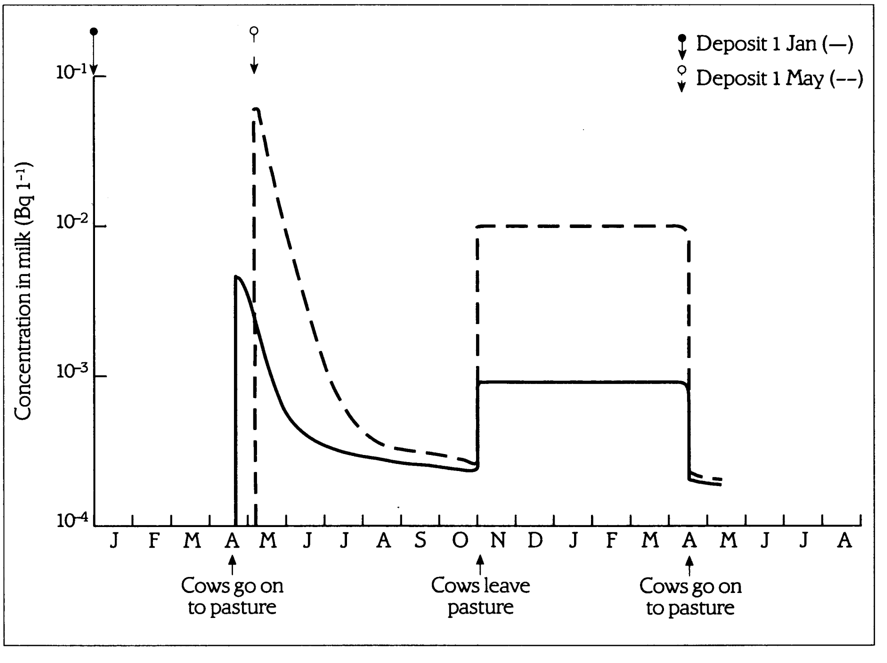
Radionuclides may become incorporated in plants either by translocation of radionuclides through the leaves (following direct deposition from the atmosphere or contaminated water, or resuspension from the soil) or by root uptake from the soil. Terrestrial animals may take up radionuclides, usually by eating contaminated feed and soil. Fish and marine life may take up radionuclides by absorbing or ingesting contaminated water or food. The rates at which radionuclide levels build up in plants and animals and the manner in which the radionuclides are distributed in the tissues depend on a complex interaction of the chemical and physical properties of the radionuclides, the amount available for uptake (which is, in turn, dependent on soil type), and the size and state of development of the animal or plant and its biological metabolism. However, a general pattern can be described in which the radionuclide levels build up to a peak and then reduce again with time. This peak may be observed for only a very short time or may be protracted, depending on the continuing availability of radionuclides for uptake. Where animals have their natural feed supplemented by uncontaminated feed for a time and this is subsequently withdrawn, or where contaminated feed is harvested and fed to the animals later in the year, a secondary peak may be observed. The time when the peak occurs following an accident varies between different plants and different animals. It may also be modified by varying agricultural practices. However, in general, this peak will occur very quickly (ie approximately instantaneously) for green vegetables subject to direct deposition from the radioactive cloud, within a few days for the milk from cows grazing in contaminated pasture, and after a few weeks for meat, fish and marine life (although, in some circumstances, radionuclide concentrations in shellfish may reach a peak after about a week). For grain, the concentration in harvested seed is highest for initial contamination occurring about a month before harvest. These patterns of time-varying contamination are summarised in Table C1 for terrestrial food products and illustrated in Figures C1–C3 for milk, meat and grain. In general, the contamination of fish and other marine life is likely to be less of a problem, since releases entering coastal waters will be widely dispersed. However, where contamination is concentrated in an inland water body, significant concentration levels of radionuclides can build up in fish, as detected after the accident at the Chernobyl nuclear plant[5].

TABLE C1
Peak concentration in milk, beef, and lamb, and time of occurrence following deposition of 1 Bq m^{-2}

Radionuclide	Peak concentration in Bq kg^{-1} (approximate time of occurrence in days)[a]				
	Milk[b]		Beef[b]		Lamb[c]
	Deposition on 1 June	Deposition on 1 Jan	Deposition on 1 June	Deposition on 1 Jan	Deposition on 1 Jan/June
^{90}Sr	1 10^{-2} (5)	1 10^{-3} (110)	2 10^{-3} (10)	2 10^{-4} (120)	2 10^{-3} (16)
^{131}I	7 10^{-2} (4)	7 10^{-7} (110)	2 10^{-2} (4)	2 10^{-7} (110)	2 10^{-2} (6)
^{137}Cs	7 10^{-2} (6)	6 10^{-3} (110)	1 10^{-1} (16)	1 10^{-2} (120)	3 10^{-1} (21)
^{239}Pu	1 10^{-6} (7)[d]	6 10^{-8} (365)	6 10^{-5} (10)[d]	3 10^{-6} (365)	1 10^{-4} (16)

Notes
(a) From reference 3.
(b) It is assumed that cattle only graze pasture from 15 April to 31 October; during the winter months it is assumed that they are fed on stored feed.
(c) It is assumed that sheep graze outside all year round and that there is no seasonal variation of uptake of radioactivity from the soil into plants. Therefore the concentration in lamb is not dependent on the time of year of the accident.
(d) Using the assumption that cattle consume contaminated fodder during the winter months, then a second peak concentration, of a similar level to the first, is likely to occur at the end of the winter.

FIGURE C1
Concentration of ^{137}Cs in milk as a function of time following a single deposit of 1 Bq m^{-2} at two different times of year[4]



In order for a food ban to be most effective in averting doses it needs to be timed to span the period of the more elevated concentrations. This means that where the peak concentration occurs soon after the accident (eg in milk) the areas in which banning may be required need to be identified quickly. Within these areas, the marketing of food can then be prohibited unless subsequent monitoring indicates otherwise. In order to delineate such areas quickly, it may necessary to rely, initially, upon indirect (and often limited) measurements (eg ground deposition) together with models that relate these

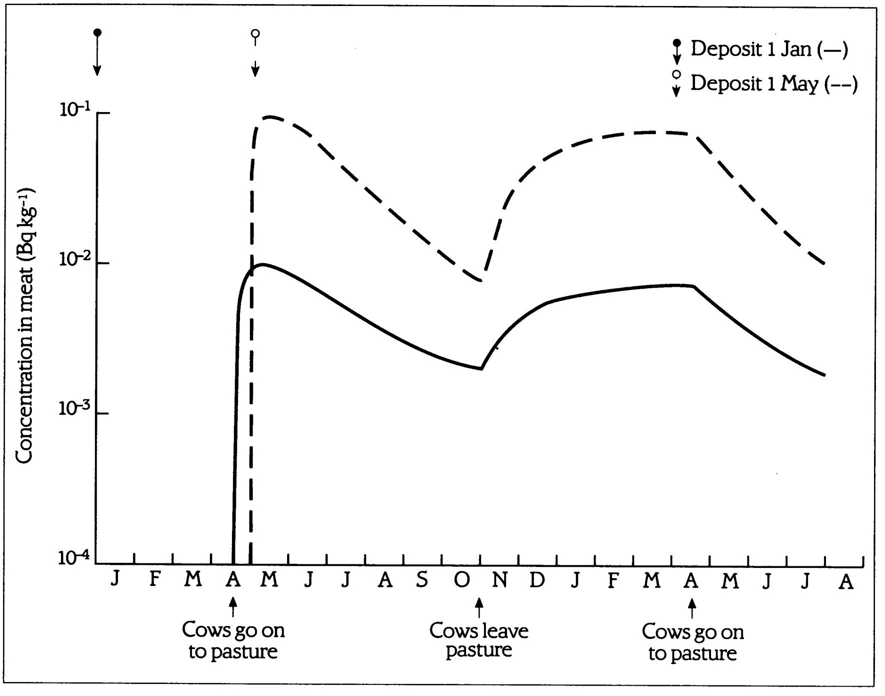


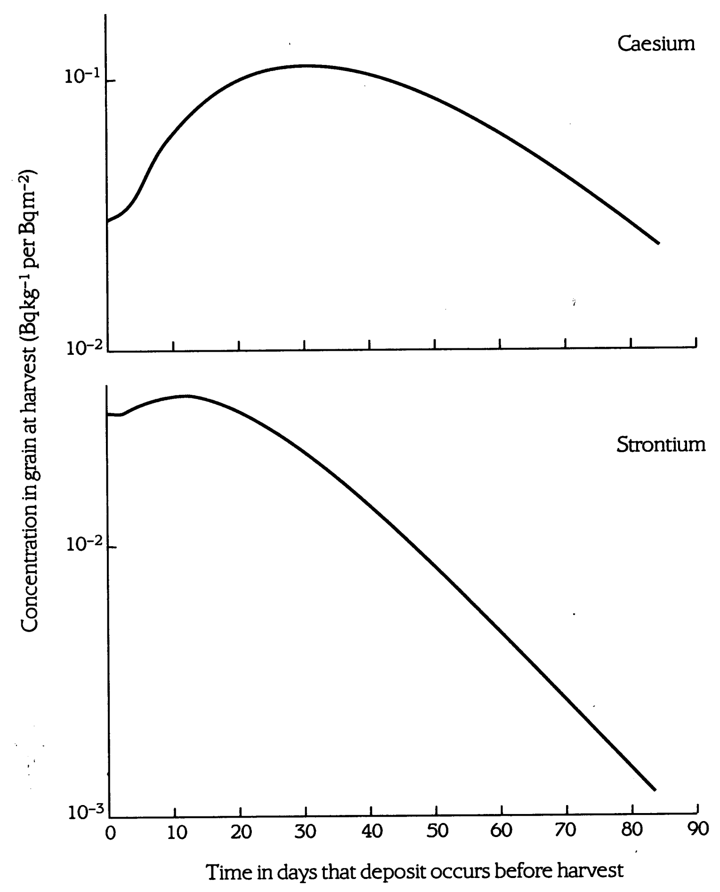
FIGURE C2
Concentration of ^{137}Cs in meat as a function of time following a single deposit of 1 Bq m^{-2} at two different times of year[4]

measurements to food concentrations. Such model predictions, although useful, will be subject to uncertainty. This is for two main reasons. First, they are likely to require quantitative input that will not be accurately known soon after an accident. Second, in order to provide predictions on a short timescale they will incorporate approximations of natural mechanisms, rather than attempt to model the environment in precise detail. As a result, models will often be operated to overestimate the consequences rather than underestimate them. Subsequent monitoring would then tend to indicate a need for less widespread restrictions than suggested by the model predictions. In this case, initial restrictions could be advised over a relatively large area. However, as more direct measurements become available, the restricted area could be reduced substantially.

Where the peak concentration does not occur for some weeks (eg in meat), then it is likely that food will not need to be banned immediately. This means that food from some areas may be freely marketed soon after the accident, but that subsequently it may be banned. Provided that the delay in banning is based on an appropriate monitoring strategy, then this situation need not give rise to concern about health risks; it is entirely a consequence of the time it takes for radionuclides deposited in the environment to reach particular types of food.

Owing to a number of factors, including varying environmental conditions in different parts of the UK, different agricultural practices (particularly those involving the feeding of animals and the timing of harvests), and the fact that deposition from a radioactive cloud would not occur simultaneously and uniformly at all locations in the UK, it is unreasonable to assume that a particular food will show the same time-varying pattern of contamination regardless of where it has been produced. In particular, the

FIGURE C3
Concentration in grain at harvest for single deposits of caesium and strontium on grain plants at various times before harvest[4]



time of occurrence of the peak concentration with respect to the time of the accident might show significant variation across the UK for a given food. The value of this peak concentration is also likely to vary across the UK, owing both to the non-uniformity of deposition that is likely to occur and also to the variation in animal feeds and crop irrigation methods and fertilisers that may be used in different regions. As mentioned previously, certain farming practices (and environmental conditions) may also give rise to subsequent peaks in concentration. This means that bans will not necessarily be implemented and lifted at the same time in all parts of the UK.

Farming countermeasures

Once certain food producing areas have been identified as likely problem areas, banning of the produce is only one of the countermeasures that could be taken. However, a detailed discussion of other methods for reducing potential contamination levels before the food leaves the farm is beyond the scope of this document. Further detail on this subject may be obtained elsewhere[6]. In summary, techniques may be applied at all stages of food production. For example, the uptake of the radionuclides from the soil may be reduced by changing the crop grown, the retention of caesium by animals may be reduced by the administration of prussian blue, and feeding animals on uncontaminated feed for a few weeks just prior to slaughter can enable natural biological processes to remove radiocaesium from the body tissues. The techniques that are most appropriate will depend on the particular circumstances (including the radionuclides present), normal farming practices and the area of land contaminated.

Food processing and preparation

Once a crop has been harvested, or an animal slaughtered, the process of preparing a food product for consumption may further modify the contamination levels observed. For example, surface contamination on fresh fruit and vegetables that are washed and/or peeled before consumption will be almost entirely removed. Immediately following an accident, when a plant has had little opportunity to absorb radionuclides, this preparation could remove a substantial part of the contamination. At later times it could be less effective, depending on the mobility of the radionuclides (ie how quickly they become incorporated within the plant). Other food products are processed in some way before becoming available to the consumer. Processing will both introduce a delay, during which time radionuclides will decay, and, for many foods, reduce the concentrations of radioactivity in the food product (although a few processes, eg the production of some types of cheese, may actually increase the radionuclide concentrations). The effectiveness of the delay time, in terms of radioactive decay, depends on the length of the delay and the half-life of the radionuclide; short-lived radionuclides, such as ^{131}I, may decay appreciably, even for delays of a week or so, whereas the concentrations of longer-lived radionuclides will only be significantly affected if the processing results in a very substantial delay (eg freezing and canning would be relevant processes for radionuclides with half-lives of months). Further information on the effects of food processing can be found elsewhere[7].

Distribution of food supplies

The distribution of food supplies within the UK is generally widespread and consequently individuals are likely to obtain most of their food from a wide variety of sources (including international sources)[8]. Moreover, most people eat a relatively varied diet, and are unlikely to rely upon one or two, potentially highly contaminated, foods. The exceptions to this dietary pattern are likely to be those individuals who grow a substantial part of their own food, and farmers, who may drink milk and eat meat or other produce from their own or neighbouring farms.

Relationship between food contamination and individual dose

From the above brief discussion, it should be clear that the concentrations of radionuclides in people's food will vary markedly, both between individuals and during the year. Moreover, the amount of each type of food consumed varies widely between individuals. It is therefore very difficult to make a direct correlation between a measured level of contamination in food from a particular source and the annual dose from ingestion which an individual is likely to receive. Mathematical models have been developed to predict the movement of radionuclides through the foodchain, under different environmental conditions, but in order to provide comprehensive predictions, detailed information concerning all levels and forms of deposition, agricultural practices, the system of monitoring and control, processing techniques, food distribution and an individual's dietary habits would be required. This is difficult to obtain for an area the size of the UK, and, in any case, behaviour patterns are likely to be modified in response to an accident in a way that is almost impossible to predict.

As discussed in the main text, the Council of the European Communities has issued Regulations specifying intervention levels (ILs) for food (here termed CFILs)[9-11]. It is clearly important, despite the complexities, to determine the general effect the CFILs will have on individual doses. In this context, it should be recognised that the CFILs will be implemented at the first point of supply (eg the farm) without regard to factors that might tend to reduce the contamination of the food before it is consumed. Within the UK, there is widespread distribution of food from its place of production to its place of consumption. Generally, only a small fraction of an individual's diet comprises locally produced foods. Moreover, as discussed above, the level of contamination in foods will vary both spatially and temporally. Only in the extreme case of an accident being so serious that a large percentage of food production was contaminated to levels greatly in excess of the CFILs would food be continually released for sale contaminated at these levels. In addition, normal processing, storage or preparation procedures are likely to reduce further the radionuclide concentrations before the food is consumed. It is therefore likely that most of the food actually consumed would be contaminated below the CFILs, even if it were originally released for supply at the CFIL levels. Thus, the annual doses received by most individuals from food would be very much smaller than the doses implied by assuming consumption of food contaminated at the CFILs for a year. Moreover, even the highest doses to individuals in the UK from food consumption would be likely to be substantially lower than those that might be implied from the assumption of continuous contamination at the CFILs. Therefore, in assessing the doses received as the result of adopting the CFILs after an accident, it is unreasonable to assume simply that all an individual's food is contaminated to that level. It is judged that an assumption of 10% of an individual's diet of a particular food type being contaminated at the CFILs will provide a cautious estimate of the upper levels of dose that would be received from that food, with the exception of those (probably very few) individuals consuming home-produced vegetables or milk which had become highly contaminated.

REFERENCES

1 Simmonds, J R, Steinhauer, C, and Haywood, S M. The transfer of radionuclides through foodchains following accidental releases to atmosphere. Luxembourg, CEC, EUR 11255 (1987).

2 Sinnaeve, J, and Gerber, G (Eds). Underlying data for derived emergency reference levels. Luxembourg, CEC, EUR 12553 (1991).

3 Brown, J, and Smith, J. Data and model parameters for applications of the FARMLAND model. Chilton, NRPB (to be published).

4 Simmonds, J R. The influence of season of the year on the transfer of radionuclides to terrestrial foods following an accidental release to atmosphere. Chilton, NRPB-M121 (1985).

5 Leonard, D R P, MAFF. Private communication (1993).

6 Howard, B J, and Dismet, G M (Eds). Proceedings of a CEC workshop on the relative effectiveness of agricultural countermeasures techniques (REACT), Brussels, October 1991. *Sci. Total Environ.*, **137** (1993).

7 IAEA. Modelling of resuspension, seasonality and losses during food processing. First report of the VAMP terrestrial working group. Vienna, IAEA-TECDOC-647 (1992).

8 Haywood, S M, Smith, J, and Walmsley, A. The impact of food movement between production and consumption on ingestion doses. IN Proceedings seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens, May 1990. Luxembourg, CEC, EUR 13013/1 (1991).

9 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

10 CEC. Council Regulation (Euratom) No. 944/89 laying down maximum permitted levels of radioactive contamination in minor foodstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L101/17 (1989).

11 CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of a radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).

Appendix D

PREPARED BY D H DODD

SENSITIVITY OF COLLECTIVE DOSE AVERTED AND MONETARY COST OF BANS TO THE INTERVENTION LEVEL ADOPTED

Introduction

A study has been undertaken to investigate the manner in which the monetary cost of imposing food restrictions and the collective dose averted by those food restrictions vary relative to each other, as the intervention level is varied. This appendix summarises the results of that study.

Methodology

The MARC-2 suite of programs[1] (methodology for assessing the radiological consequences of accidental releases of radionuclides to the atmosphere) was used to obtain the cost of implementing the food restrictions and the collective dose averted for each of a set of intervention levels (ILs). This was repeated for two different release scenarios as described below.

Release scenarios considered

Two release scenarios were considered, both based on the core inventory of a pressurised water reactor (PWR). The first was a hypothetical release of approximately 1% of the core inventory (HRA) and the second was a smaller release, characteristic of a containment bypass accident (HRB). For each scenario, the implications for implementing food restrictions were calculated assuming a combined release of ^{137}Cs and ^{134}Cs only. Although only radiocaesium was considered, the results (in terms of the relative sensitivity of collective dose averted and monetary cost to changes in the IL) are likely to be representative of those that would result from the release of most radionuclides that might significantly contaminate food supplies. The magnitudes of the assumed releases are given in Table D1.

The releases were assumed to occur at an agricultural site with a single set of constant meteorological conditions for each release (Pasquill stability D, windspeed 5 m s^{-1}, no rain). Three wind directions (nominally the 'best', 'worst', and 'typical' in terms of agricultural consequences) were analysed, in order to investigate the sensitivity of the cost and effectiveness of different ILs for a wide range of consequences. The releases were assumed to occur in early summer. In terms of agricultural consequences this is between the extremes of winter, when not many crops are grown and many livestock are indoors, and late summer, just before the harvesting of grain crops and when sheep and cattle are outdoors[3].

TABLE D1
Releases assumed[a]

Radionuclide	HRA[b] (Bq)	HRB[c] (Bq)
^{134}Cs	4 10^{15}	8 10^{14}
^{137}Cs	2 10^{15}	5 10^{14}

Notes
(a) Releases based on the core inventory of a PWR[2].
(b) Release of 1% of the core inventory.
(c) Release representing a containment bypass accident[2].

The ILs used for implementing the bans were multiples of the Council Food Intervention Levels (CFILs) laid down in Regulations issued by the Council of the European Communities[4-6]. Food restrictions were assumed to be lifted at the same criteria as those at which they were imposed. Results were obtained for no intervention and with bans implemented over the range from 0.5 to 20 times the CFILs. The results have been compiled for three food pathways; livestock (comprising lamb and beef), milk, and crops (comprising grain and green vegetables). It was decided not to divide the food pathways further as sufficiently disaggregated cost data are not available for the UK. For the two compound pathways, livestock and crops, the length of the ban is defined by the most restrictive ban for the two component pathways.

Economic model

The COCO-1 economic consequence model provided the basic methodology for assessing the cost of restrictions on agricultural produce[7]. The broad economic definition of cost is benefit foregone. The benefit foregone can be measured by the amount of money that would be required to restore the individuals, businesses, and public bodies concerned to their original level of well-being, ie the amount of income lost. In COCO-1 the contribution of each food to the gross domestic product (GDP) is used as the basic measure of income lost. The cost figures include the lost income from the banned food and the cost of the lost services of agricultural capital (land and buildings). For each food pathway COCO-1 provides cost data for three periods: 0 to 1 year, 1 year to economic recovery (assumed in the present study to be 5 years), and time following economic recovery. The data for the first two periods are given in Table D2. The values for the first year include the GDP contribution and costs of such things as feed and fertiliser (which are assumed not to continue beyond the first year). The assumption is made in COCO-1 that the only costs following economic recovery will be the lost investment associated with agricultural land and buildings. These costs are region dependent; those assumed for the agricultural site are given in Table D3. MARC-2 was modified to incorporate the time and region dependent cost data from the COCO-1 economic consequence model. A discount rate of 5% per year was assumed in this study.

TABLE D2
Food cost data as a function of time[7]

	Cost	
Food	0–1 year	1 year – t_r
Crops (£ km^{-2})	102 000	37 000
Livestock (£ per head)	260	80
Milk (£ l^{-1})	0.25	0.08

Note t_r is the economic recovery time, taken here to be 5 years.

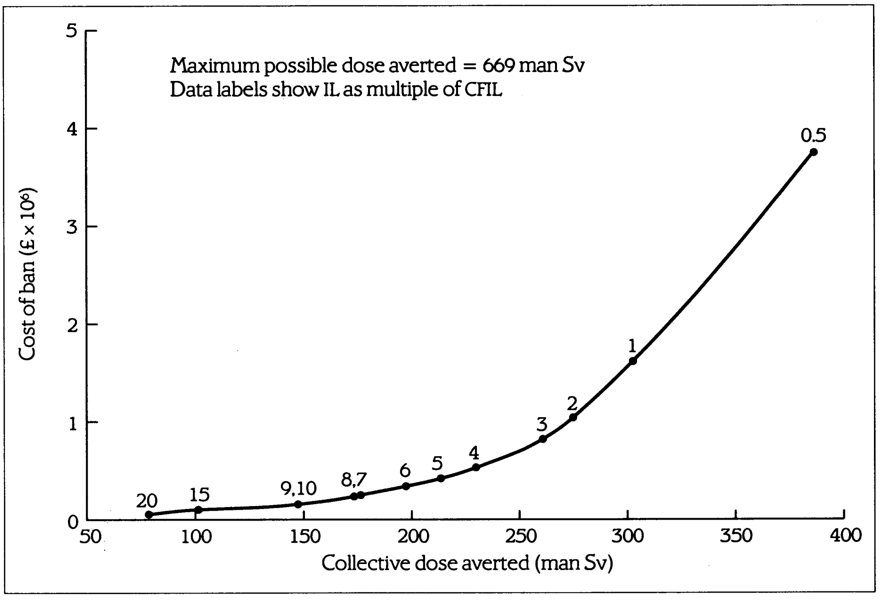
TABLE D3
Capital services costs[7]

Food	Cost
Crops (£ km^{-2})	18 140
Livestock (£ per head)	80
Milk (£ l^{-1})	0.02

Results

The sensitivity of the monetary cost of bans and collective dose averted can be obtained by plotting the cost of the protective action against the collective dose averted associated with each protective option. Figure D1 shows a typical cost–effectiveness curve for milk contaminated with radiocaesium obtained from this study. It clearly illustrates the 'law of diminishing returns' in that it becomes increasingly more expensive to avert collective dose with decreasing IL.

FIGURE D1 *Illustrative cost–effectiveness analysis curve*



Tables D4 and D5 show the change in collective dose averted and the monetary cost associated with changing ILs for releases HRA and HRB, respectively. In each case, these results are given for the wind direction judged to give typical consequences. The tables show that the factor increase of costs between ILs is significantly larger than the factor increase of dose averted, for both releases, for all three food categories, and over a wide range of changes in the IL. In other words, for each incremental lowering the IL (ie making it more restrictive), the monetary cost of averting unit collective dose increases. This is a consequence of the rapid increase in area over which food must be restricted, as ILs are reduced. Clearly, the precise value of these factor increases is dependent on the agricultural distribution around the chosen site and the characteristics of the accident. However, the purpose of this study was to demonstrate the trend that the monetary cost varies more rapidly with changes in IL than does the collective dose averted; the purpose was not to derive values for generic application.

The final column in Tables D4 and D5 summarises the results by showing the ratio between the increase in cost and the increase in dose averted for each change in IL. A number greater than unity indicates that monetary costs are changing more rapidly than the collective dose averted. This ratio is also shown for the other wind directions studied, thus demonstrating that the trend illustrated for the 'typical' wind direction occurs more generally. This conclusion agrees with results obtained elsewhere[8].

TABLE D4
Implications of changes in the intervention level for release HRA[a]

Food	Change in intervention level (relative to CFIL)	Approximate change in cost	Approximate change in collective dose averted	Ratio[b]	
Milk	÷2	×5	×2	2.5	(1.2, 2.1)
	×2	÷2.5	÷1.5	1.8	(1.1, 1.6)
	×10	÷40	÷4	9.5	(3.5, 6.8)
Crops	÷2	×2.5	×1.5	1.9	(1.1, 2.3)
	×2	÷3	÷1.5	2.0	(1.4, 2.0)
	×10	÷25	÷3	8.2	(4.8, 5.2)
Livestock	÷2	×3	×1.5	1.7	(1.4, 1.2)
	×2	÷2.5	÷1.5	1.6	(1.3, 1.3)
	×10	÷20	÷4.5	5.0	(2.1, 15.9)

Notes
(a) These results are for the wind direction giving 'typical' consequences.
(b) Calculated as change in cost divided by change in collective dose averted (using unrounded cost and dose ratios). For perspective, the figures in brackets indicate the corresponding ratios obtained for the 'best' and 'worst' wind directions, respectively.

TABLE D5
Implications of changes in the intervention level for release HRB[a]

Food	Change in intervention level (relative to CFIL)	Approximate change in cost	Approximate change in collective dose averted	Ratio[b]	
Milk	÷2	×3.5	×1.5	2.3	(1.6, 1.8)
	×2	÷2.5	÷1.5	1.8	(1.8, 1.5)
	×10	÷30	÷4	7.9	(9.0, 4.2)
Crops	÷2	×3	×1.5	2.1	(1.7, 1.6)
	×2	÷2.5	÷1.5	1.8	(1.9, 1.5)
	×10	÷30	÷4	7.7	(11.5, 7.7)
Livestock	÷2	×2.5	×1.5	1.6	(1.2, 3.0)
	×2	÷2	÷1.5	1.5	(1.3, 2.7)
	×10	÷20	÷3	6.0	(5.2, 8.7)

Notes
(a) These results are for the wind direction giving 'typical' consequences.
(b) Calculated as change in cost divided by change in collective dose averted (using unrounded cost and dose ratios). For perspective, the figures in brackets indicate the corresponding ratios obtained for the 'best' and 'worst' wind directions, respectively.

REFERENCES

1 Jones, J A, Stather J W, Brown, J, Williams, J A, and Haywood, S M. MARC-2A – the 1989/90 version of the MARC program. Chilton, NRPB-M222 (1990).

2 Jones, J A, and Williams, J A. Assessment of the radiological consequences of releases from containment bypass accidents from a proposed PWR at Hinkley Point, using MARC-1. Chilton, NRPB-M154 (1988).

3 Simmonds, J R. The influence of season of the year on the transfer of radionuclides to terrestrial foods following an accidental release to atmosphere. Chilton, NRPB-M121 (1985).

4 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

5 CEC. Council Regulation (Euratom) No. 944/89 laying down maximum permitted levels of radioactive contamination in minor foodstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L101/17 (1989).

6 CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of a radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).

7 Haywood, S M, Robinson, C A, and Heady, C. COCO-1: Model for assessing the cost of offsite consequences of accidental releases of radioactivity. Chilton, NRPB-R243 (1991) (London, HMSO).

8 Crick, M J. Derived intervention levels for invoking countermeasures in the management of contaminated environments. IN Proceedings international seminar on intervention levels and countermeasures for nuclear accidents, Cadarache, France, October 1991. Luxembourg, CEC, EUR 14469 (1992).

Appendix E

CONTAMINATION OF WATER FOLLOWING ACCIDENTS

Introduction

It is extremely unlikely that drinking water supplies will become contaminated to levels that would pose a significant threat to health, following an accidental release of radionuclides, either within the UK or abroad. This is because such levels of contamination would require a very large release. However, it is still prudent to determine what action would be appropriate in the remote eventuality of such a large release.

Contamination of water bodies

Water supplies can be contaminated either directly or indirectly following an accidental release of radionuclides. Direct contamination will result from a discharge into a water body. Such contamination will be largely localised in terms of contamination of the drinking water supply, affecting only water extracted near to or downstream from the discharge point. However, the contamination may continue for a long time, either because the water body is fairly enclosed (eg a lake or reservoir) or because radionuclides become incorporated in sediments and later remobilised into the liquid phase.

Radionuclides released to the atmosphere may contaminate a wide range of drinking water sources as a result of dispersion and transfer in the environment. Radionuclides may be deposited on to water surfaces by either wet or dry deposition, rainwater itself may be contaminated, and radionuclides deposited on to solid surfaces may be washed or leached into water bodies. Once water bodies have become contaminated, the processes of deposition on to, and desorption from, sediment may again be important.

It is clear that the contamination of water supplies resulting from atmospheric releases would be potentially more widespread than that from accidental discharges to water. Although the local contamination levels are likely to be higher in the latter case, it should be possible to isolate a single contaminated source of water, such that the consequences are contained. For this reason, this appendix concentrates on the contamination of drinking water following an accidental release to the atmosphere.

The contamination of rainwater has been briefly mentioned. In the UK, some individuals rely for their main water supply exclusively upon direct rainwater or other supplies that are likely to be significantly affected by contaminated rainwater. However, it is unlikely that rain will be contaminated for a long time. It is the total cumulative intake of radionuclides that determines the degree of harm. Therefore, although these individuals may consume relatively highly contaminated water for short periods, the dose they receive is unlikely to be high.

Chernobyl experience

UK water supplies were contaminated as a result of the accident at the Chernobyl nuclear plant and this experience provides some useful background information. A 1986 publication provided a compilation of environmental measurements immediately following the arrival of the plume in the UK, the results of which provide a valuable insight into the behaviour of radionuclides following an accidental release to the atmosphere[1]. This publication included measurements of activity concentrations in rainwater and surface waters in various parts of the UK. Generally, the maximum concentrations of radiocaesium and radioiodine in rainwater were up to about 10 000 and 3000 Bq l^{-1}, respectively, although isolated measurements (in puddles, ie non-potable water) as high as 28 000 Bq l^{-1} of ^{131}I were made in Scotland. These are in excess of the intervention levels for liquid foods laid down by the Council of the European Communities[2] (CFILs of 1000 and 500 Bq l^{-1}). Concentrations of ruthenium isotopes in rainwater also approached the CFIL for liquid foods for these radionuclides. However, the maximum concentrations of radionuclides in surface waters, eg rivers, lakes and reservoirs, were generally well below the CFILs for liquid foods (eg less than 20 Bq l^{-1} of ^{137}Cs in Cumbrian reservoirs). (It is interesting to note that levels of radiocaesium in the Kiev reservoir also remained well below the CFIL for longer-lived radionuclides in liquid foods.) The concentrations of radionuclides in underground water supplies and 'tap' water were generally found to be negligible.

The doses received as a result of this contamination are useful for perspective. Individual doses from caesium contamination in the year following the accident have been estimated[3]. These calculations were based on data chosen to be representative of the most contaminated reservoirs. The maximum radionuclide concentrations of ^{134}Cs and ^{137}Cs were 0.12 and 0.25 Bq l^{-1}, respectively. The average concentrations of these isotopes over the first year were 0.06 and 0.14 Bq l^{-1}, respectively. A hypothetical individual, assumed to obtain all his drinking water from the reservoir for 1 year, was estimated to receive less than 2 μSv over this period. This is three orders of magnitude lower than the average annual dose to members of the public from natural radiation and therefore insignificant. Moreover, in most cases, the radionuclide concentrations measured in surface waters in England and Wales were significantly lower than this. The maximum activity concentration measured in other river and reservoir systems in England and Wales was 0.04 Bq l^{-1}. The mean activity of ^{137}Cs for the whole of 1986 was generally a factor of two lower than the peak concentration.

A review of the effect of accidental releases of activity on water supplies by the Department of the Environment (DoE)[4] also highlighted the following points that may be important for planning purposes.

(a) Water bodies may be ranked in terms of their susceptibility to contamination from atmospheric releases in the order: rainwater, lakes and reservoirs, rivers, groundwaters. However, it should be noted that high concentrations in rainwater remain only for a short period, whereas the elevated concentrations in lakes and reservoirs may persist for some time.

(b) Water treatment processes act partly to decontaminate supplies. The effectiveness of these processes depends on the radionuclides concerned as shown in Table E1. The conclusion can be drawn that even if surface waters are contaminated above a given action level, the levels in tap water may be significantly lower. It is therefore important that activity concentrations are measured following any routine treatment operations. If measurements are made on surface waters in order to identify potential problem areas, then such measurements should normally consider only the liquid phase and not suspended sediment.

TABLE E1
Effects of water and sewage treatment methods on the concentrations of radionuclides in water[a]

Treatment method	Gross activity removal
Rapid sand filter	44%-78%
Slow sand filter	51%
Advanced treatment[b]	78%-90%
Sewage treatment	80%
For the removal of specific radionuclides	
Iodine	Sand is not effective but activated carbon can remove up to 90% of the activity
Caesium (particulate)	50% removed by sand
Strontium	Poorly removed except by 'lime softening' (80%) or ion exchange techniques (99%)
Ruthenium	Reduced by up to 80% (by sand)

Notes
(a) From the report of the Joint Working Group on Water Services[4]. Further information may be obtained elsewhere[5].
(b) This method includes coagulation, sedimentation, rapid gravity filtration and activated carbon absorption.

(c) The effect of thermal stratification on the contamination of a lake means that deposition occurring during the summer months will produce higher surface water concentrations than would occur following deposition during the winter.

Work carried out at the Board[5,6] supports the DoE conclusions, and, in particular, demonstrates the fact that contamination of drinking water supplies is unlikely to make a significant contribution to the health consequences following an accidental release of radionuclides to the atmosphere; these are likely to be dominated by external irradiation from deposited radionuclides and contaminated terrestrial foods.

Factors other than health consequences

The health consequences resulting from contaminated drinking water supplies are only one consequence that should be considered when making decisions on what action level to set for banning water supplies. The monetary cost and social disruption incurred should also be taken into account. It is likely that if drinking water restrictions (other than for unblended contaminated rainwater) are imposed, then they may contribute significantly to the disruption and anxiety experienced by members of the public.

Practical implications of adopting the Board's recommended Action Levels for water

The Board has recommended UK Action Levels for drinking water supplies, taking account of the upper levels of dose some individuals might receive. Based on the foregoing discussion, it seems clear that, even following a very serious nuclear accident, radionuclide concentrations in UK drinking water supplies are unlikely to exceed these Action Levels. The only possible exceptions to this are drinking water supplies solely comprising unblended contaminated rainwater, and accidents involving significant radioactive discharges directly to water bodies supplying mains water services. Where rainwater forms a significant supply, it is unlikely that this supply would continue to be heavily contaminated for many days. The likelihood, in the UK, of significant accidental releases into a water body used for drinking water supply is very low. Moreover, as discussed above, the extent of contamination resulting from a release directly to a water body would be restricted, thereby enabling resources to be concentrated in a limited area. Thus, implementation of the Action Levels is unlikely to cause significant disruption to drinking water supplies in the UK. Except for a very severe accident, it is unlikely that any supplies other than those obtained from unblended contaminated rainwater would need to be restricted.

REFERENCES

1 Department of the Environment. Levels of radioactivity in the UK from the accident at Chernobyl USSR on 26 April 1986, a compilation of the results of environmental measurements in the UK. London, HMSO (1986).

2 CEC. Council Regulation (Euratom) No. 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L371/11 (1987), amended by Council Regulation 2218/89. *Off. J. Eur. Commun.*, L211/1 (1989).

3 Department of the Environment. Chernobyl: Evaluation and radiological assessment of factors affecting drinking water supplies. London, DoE, DOE/RW/90/008 (1990).

4 Department of the Environment/Welsh Office. The impact of accidental releases of radioactivity on water services. London, Department of the Environment Water Inspectorate, Report by the Joint Working Group on Water Services (1990).

5 Dionian, J, and Linsley, G S. Models for the transfer of radionuclides from atmosphere into drinking water supplies. Chilton, NRPB-M90 (1983).

6 Dionian, J, NRPB. Private communication (1989).

Documents of the NRPB

VOLUME 1 (1990)

No. 1 Radiological Protection Act 1970
Board Statement on Limitation of Human Exposure to Radon in Homes

No. 2 Gut Transfer Factors

No. 3 Patient Dose Reduction in Diagnostic Radiology

No. 4 Board Statement on Emergency Reference Levels
Radon Affected Areas: Cornwall and Devon

VOLUME 2 (1991)

No. 1 Board Statement on Clinical Magnetic Resonance Diagnostic Procedures

VOLUME 3 (1992)

No. 1 Electromagnetic Fields and the Risk of Cancer

No. 2 Board Statement on Approval of Consumer Goods Containing Radioactive Substances

No. 3 Board Statement on Radiological Protection Objectives for the Land-based Disposal of Solid Radioactive Wastes

No. 4 Protection of the Patient in X-ray Computed Tomography
Radon Affected Areas: Derbyshire, Northamptonshire and Somerset

VOLUME 4 (1993)

No. 1 Board Statement on the 1990 Recommendations of ICRP

No. 2 Occupational, Public and Medical Exposure

No. 3 Dose Quantities for Protection Against External Radiations

No. 4 Board Statement on Diagnostic Medical Exposures to Ionising Radiation During Pregnancy
Estimates of Late Radiation Risks to the UK Population

No. 5 Board Statement on Restrictions on Human Exposure to Static and Time Varying Electromagnetic Fields and Radiation

No. 6 Radon Affected Areas: Scotland, Northern Ireland

CONTENTS

On sale through HMSO
Price £5.00

ISSN 0958-5648

ISBN 0-85951-371-8

HMSO bookshops
49 High Holborn, London WC1V 6HB
71 Lothian Road, Edinburgh EH3 9AZ
9/21 Princess Street, Albert Sq, Manchester M60 8AS
Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
16 Arthur Street, Belfast BT1 4GD

Government publications are also available through booksellers.

Documents of the NRPB, Vol 5, No 1, 1994